

Top Quark Properties from top pair events and decays



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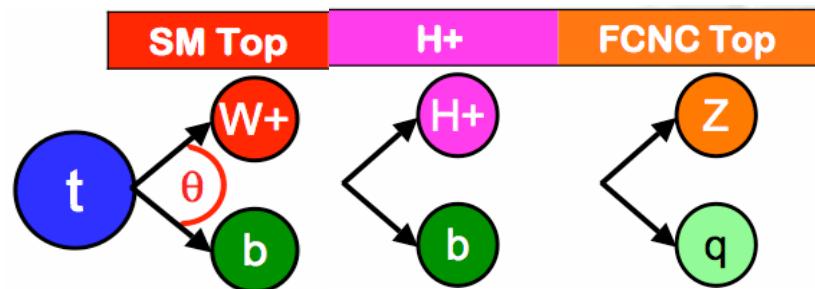
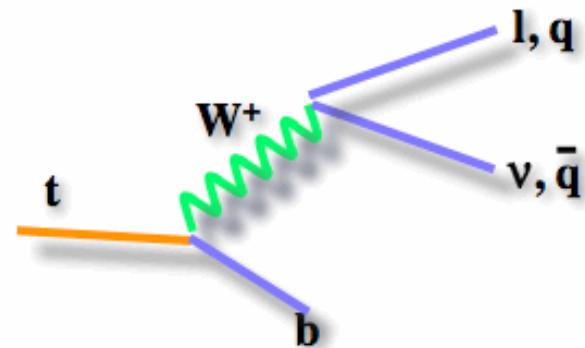


For CDF and D0 Collaborations

**34th International Conference on High Energy Physics,
ICHEP 2008 Philadelphia, USA**

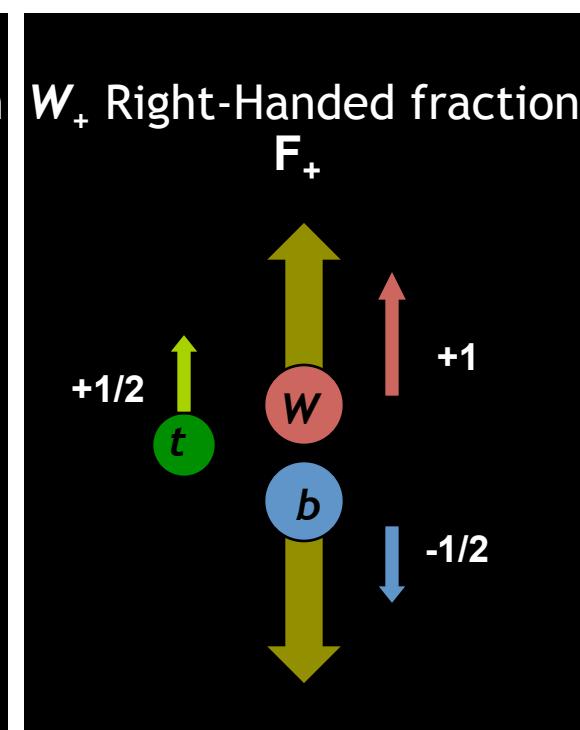
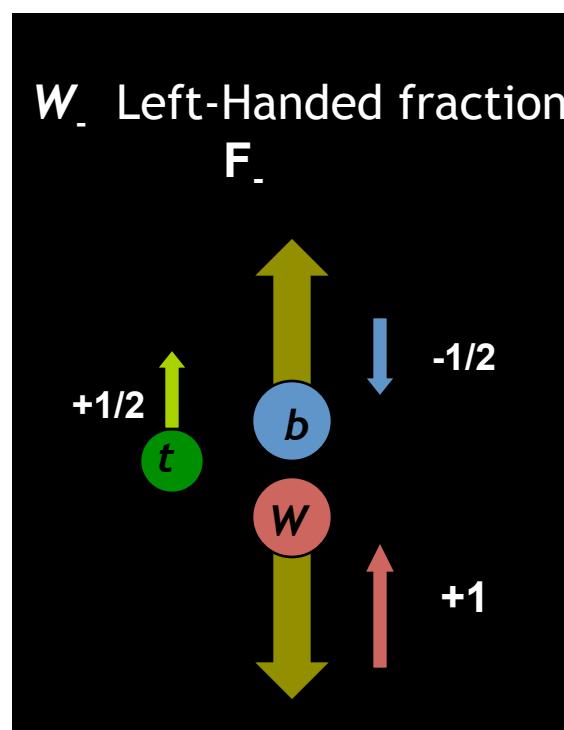
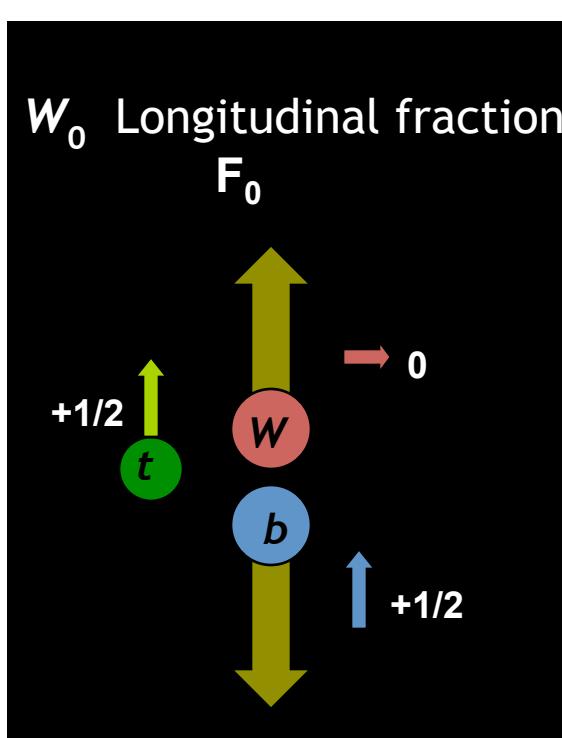
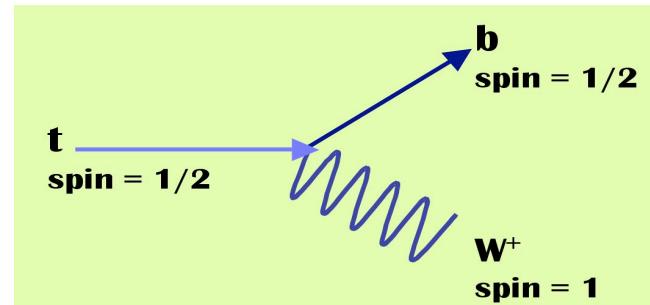
Top Properties Analyses

- Within the SM the top quarks decays into Wb
- Probing the nature of $t \rightarrow Wb$ vertex:
 - W Helicity Measurement
- Can the top quark decay into other particles?
 - $\text{BR}(t \rightarrow Wb) / \text{BR}(t \rightarrow Wq)$
 - Search for Charged Higgs
 - Search for FCNC top decays
 - Search for Invisible Top Decays



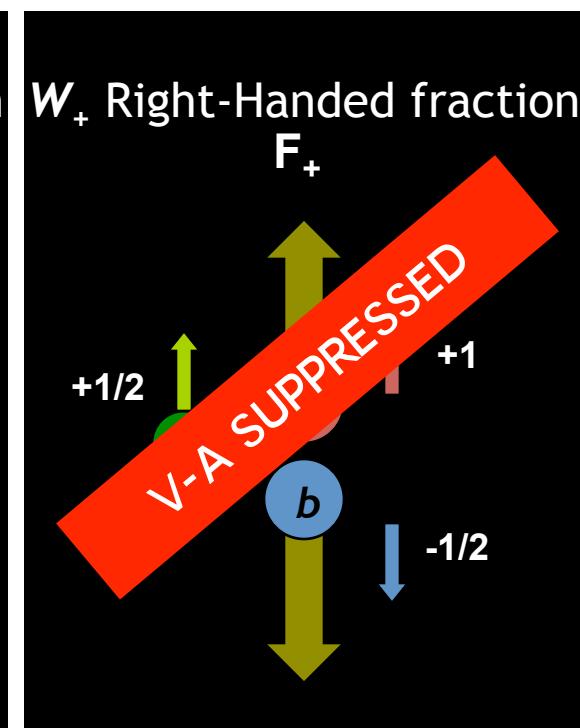
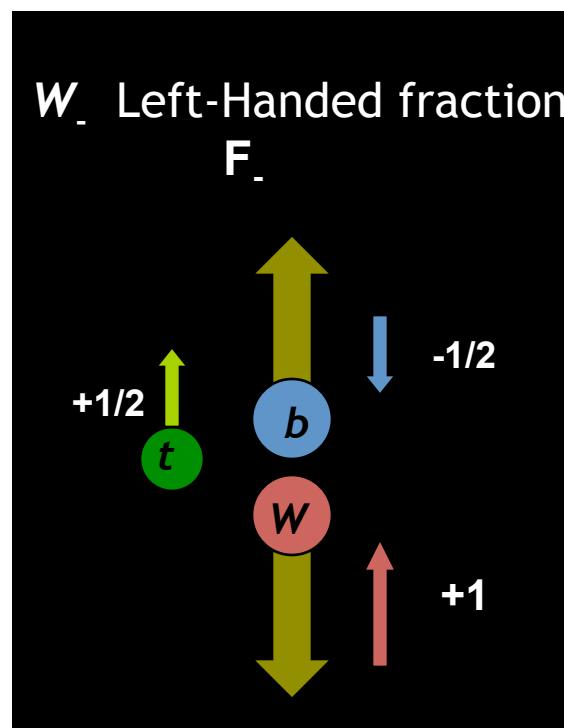
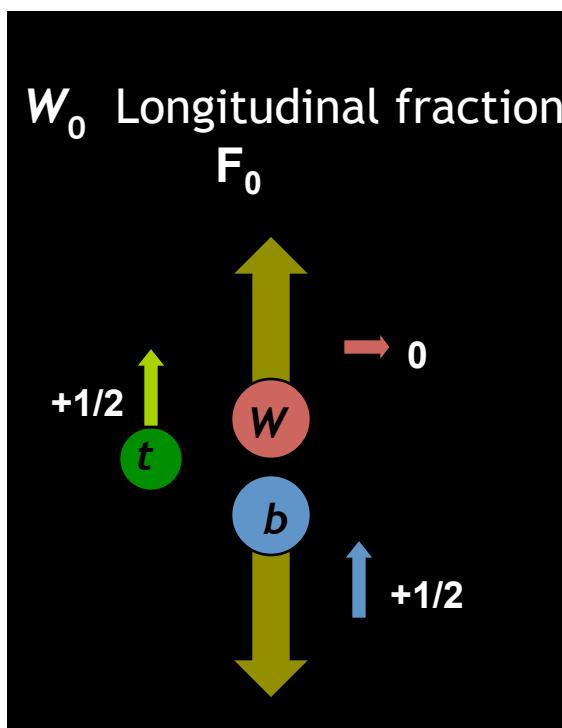
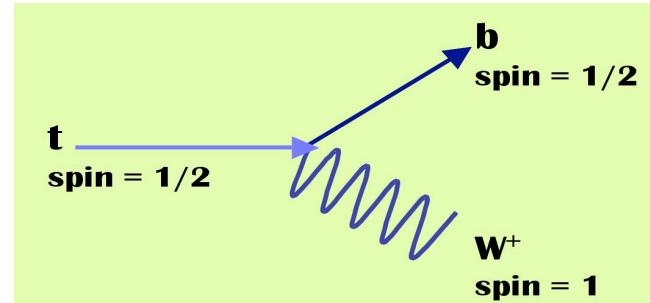
W Helicity

- Spin information of the top quark is preserved in its decay products
- Examining the V-A nature of $t \rightarrow W b$ vertex provides stringent test of the SM



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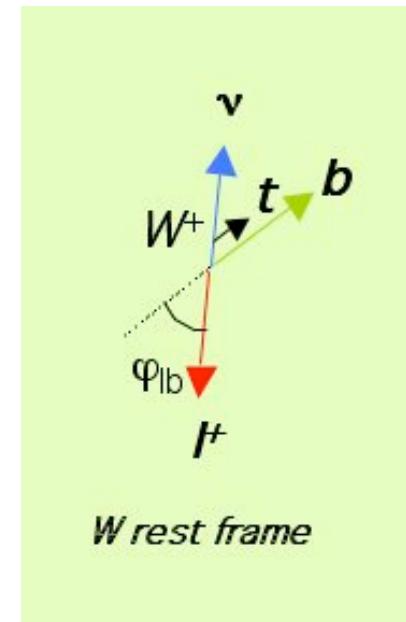
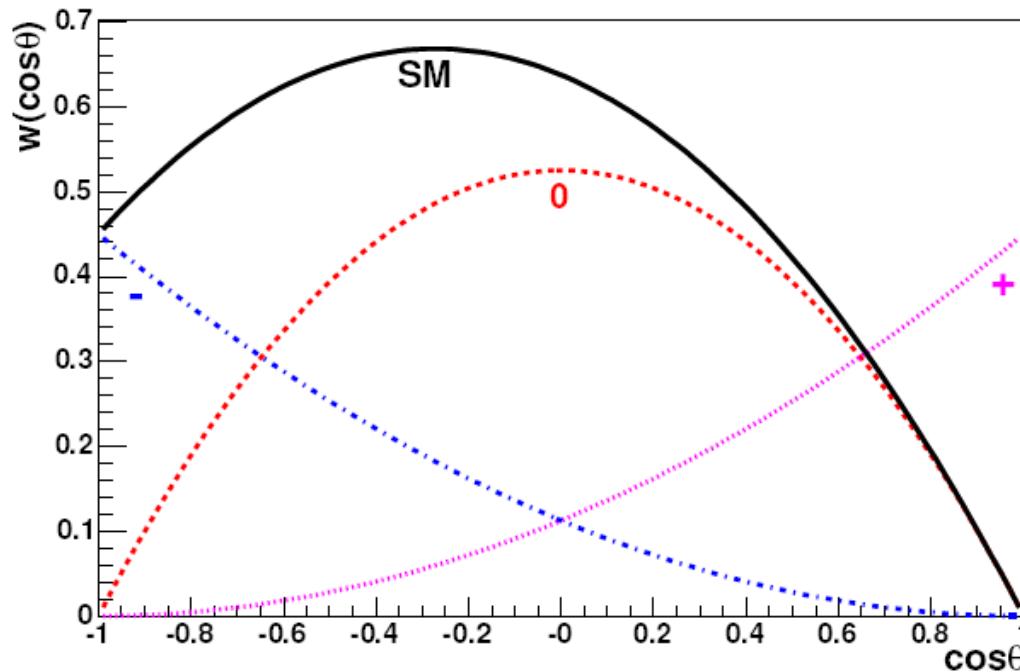


W Helicity

- In the Standard Model :

$$w(\cos\varphi_{l\bar{b}}) = F_- \cdot \frac{3}{8}(1 - \cos\varphi_{l\bar{b}})^2 + F_0 \cdot \frac{3}{8}(1 - \cos^2\varphi_{l\bar{b}}) + F_+ \cdot \frac{3}{8}(1 + \cos\varphi_{l\bar{b}})^2$$

$$F_- = 0.3 \quad F_0 = 0.7 \quad F_+ = 3.6 \times 10^{-4}$$



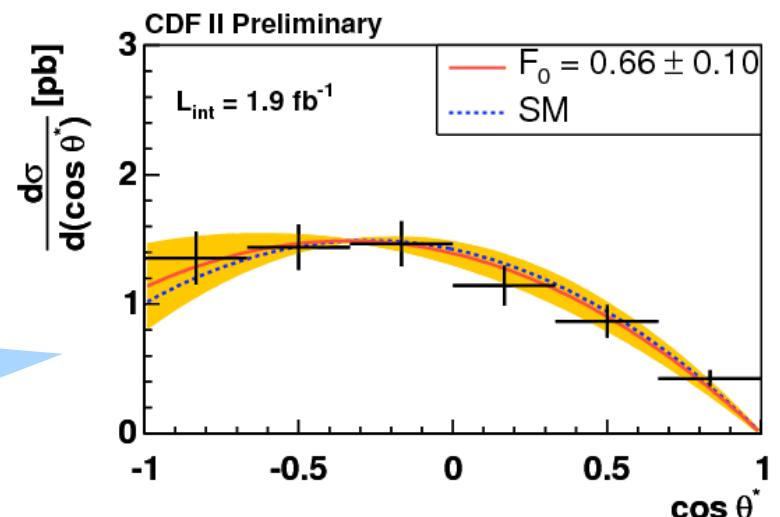
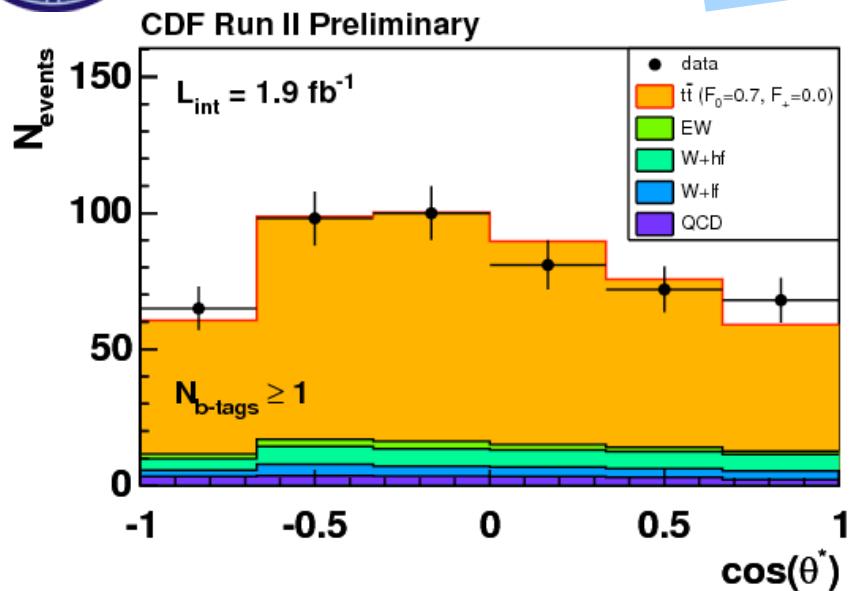
- Measure angle between the lepton direction in the W rest frame and the W boson direction in the top rest frame

W Helicity Measurement

- 1. Full Reconstruction of $\cos \theta^*$**

“unfolding” the true distribution:

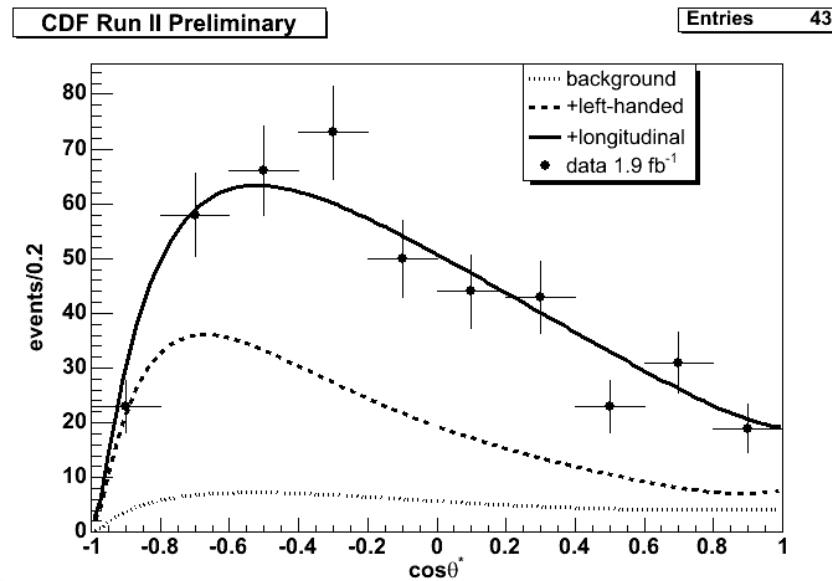
- applying event selection efficiency
- and event reconstruction migration matrix



$F_0 = 0.66 \pm 0.10(\text{stat}) \pm 0.06 (\text{syst})$
 $F_+ < 0.12$ at 95% C.L.

W Helicity Measurement

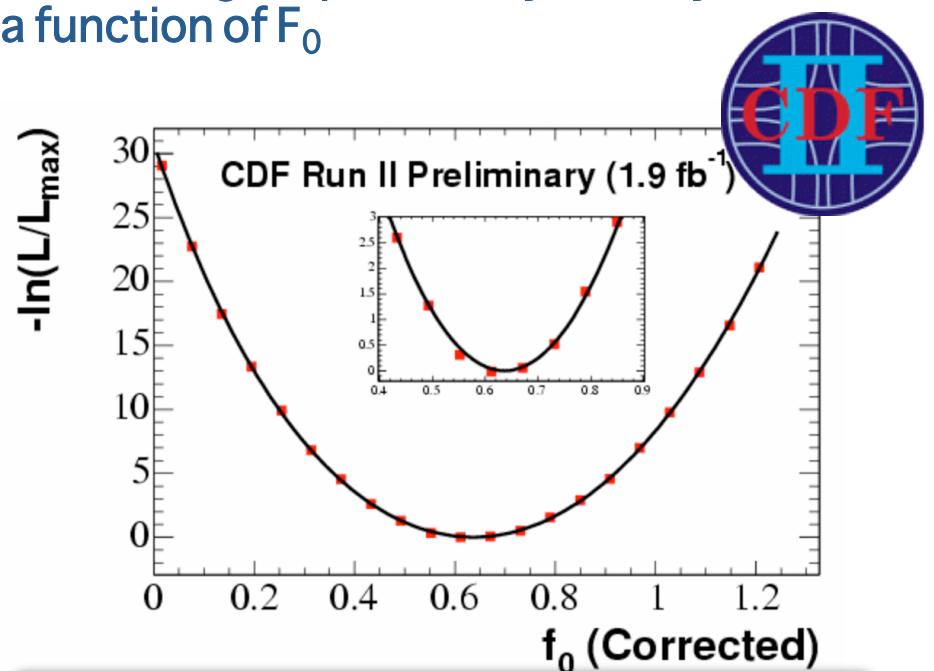
- **2. Template method $\cos \theta^*$**
- fit to the combination of templates



$$F_0 = 0.59 \pm 0.11(\text{stat}) \pm 0.04 (\text{syst})$$

$$F_+ < 0.07 \text{ at } 95\% \text{ C.L.}$$

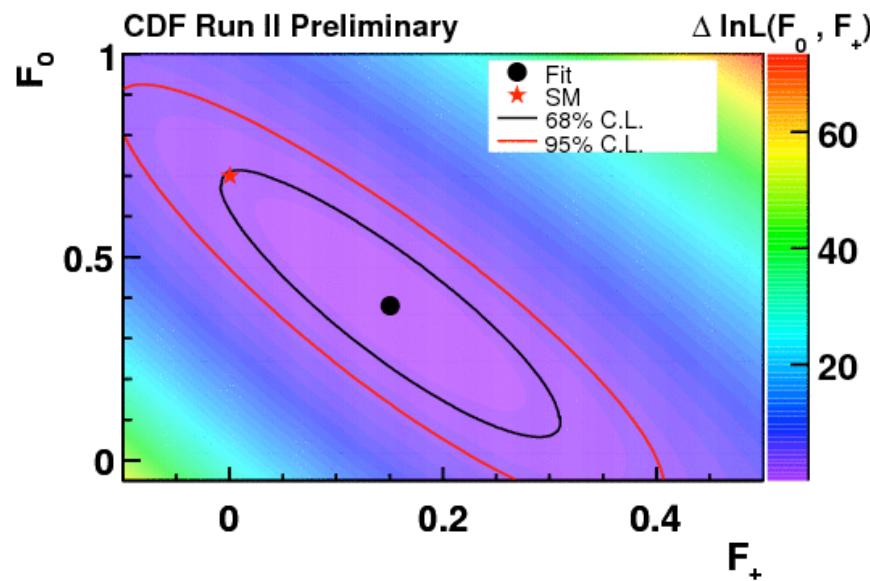
- **3. Matrix Element Method**
- utilizing ME probability density as a function of F_0



$$F_0 = 0.64 \pm 0.08(\text{stat}) \pm 0.07 (\text{syst})$$

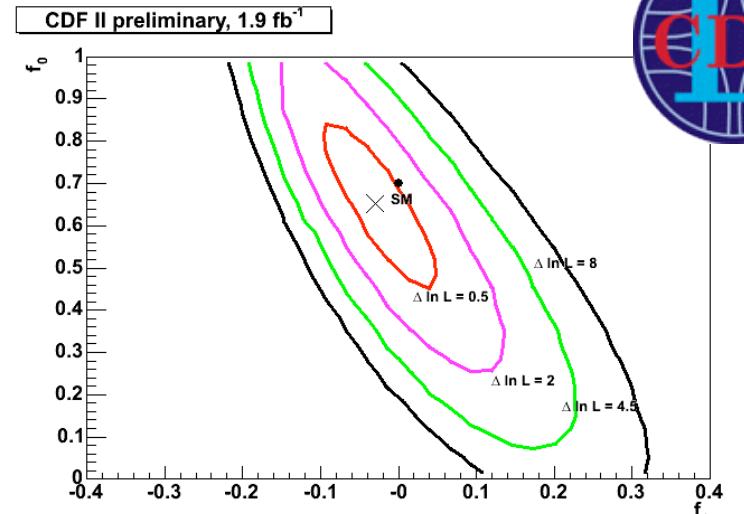
W Helicity Measurement

- **1. Full Reconstruction of $\cos \theta^*$**



2-D Combination:
 $F_0 = 0.66 \pm 0.16$
 $F_+ = -0.03 \pm 0.07$

- **2. Template method $\cos \theta^*$**



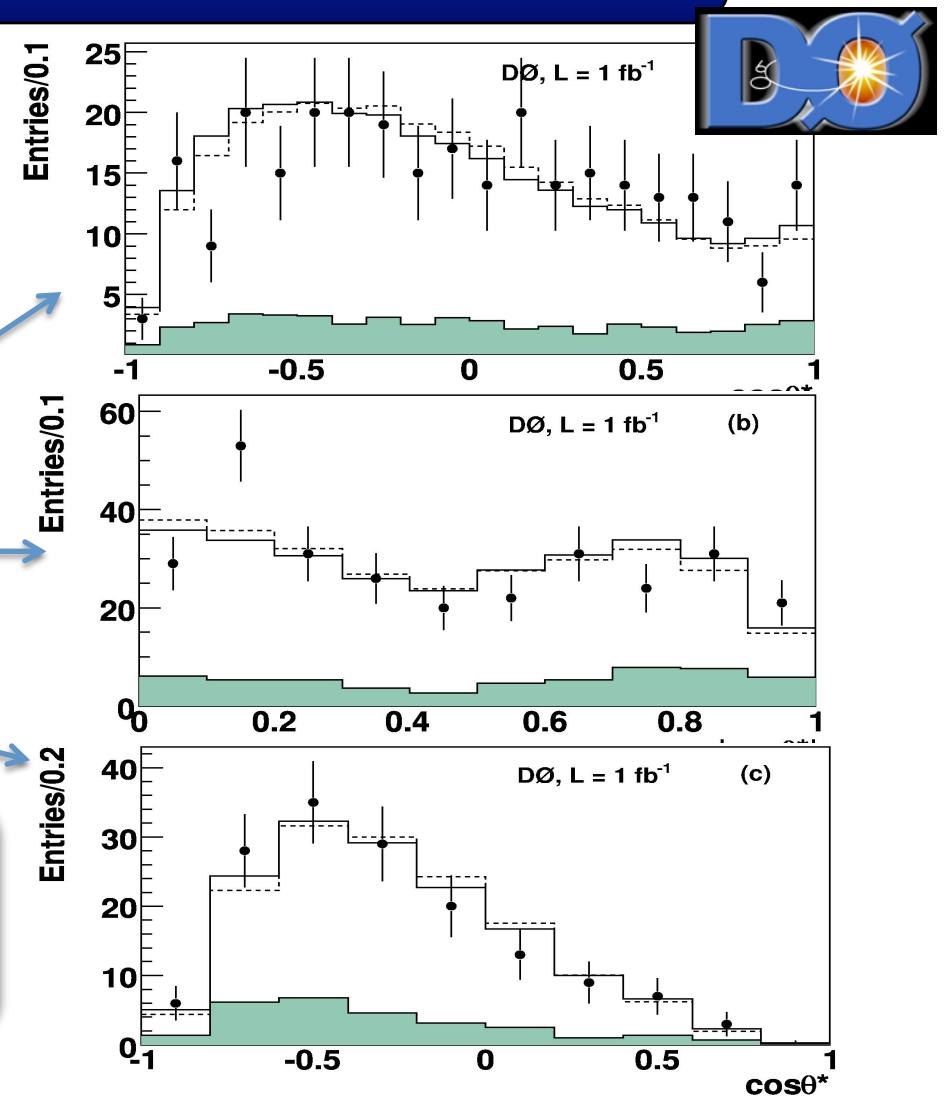
- With more statistics we start doing simultaneous fits for F_0 and F_+
- Results in good agreement with the SM

W Helicity Measurement

- Utilize several channels
- Use the binned likelihood fit $L(F_0, F_+)$

- Leptonic W decays ($l+jets$)
- Hadronic W decays ($l + jets$)
- Dilepton events

2-D:
 $F_0 = 0.49 \pm 0.11(\text{stat}) \pm 0.09 (\text{syst})$
 $F_+ = 0.11 \pm 0.06(\text{stat}) \pm 0.05 (\text{syst})$



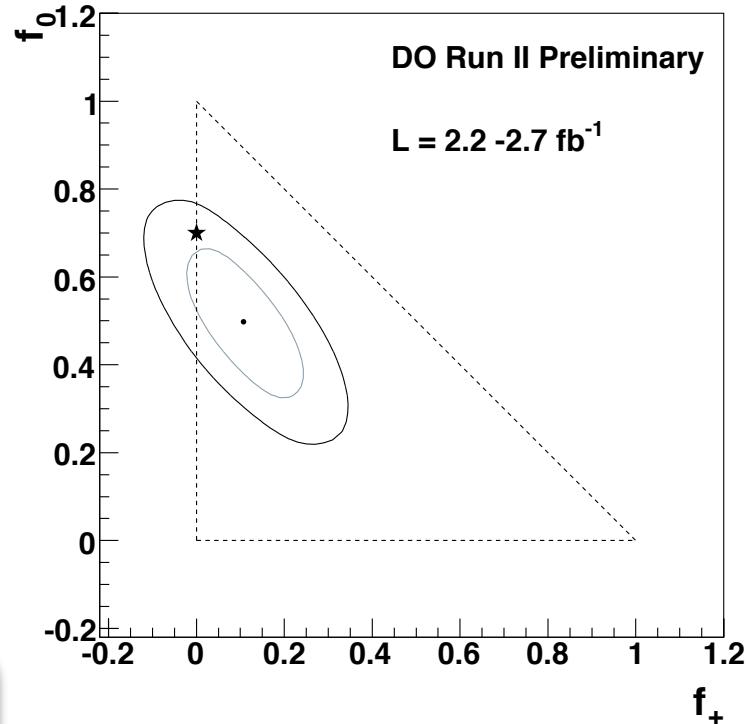
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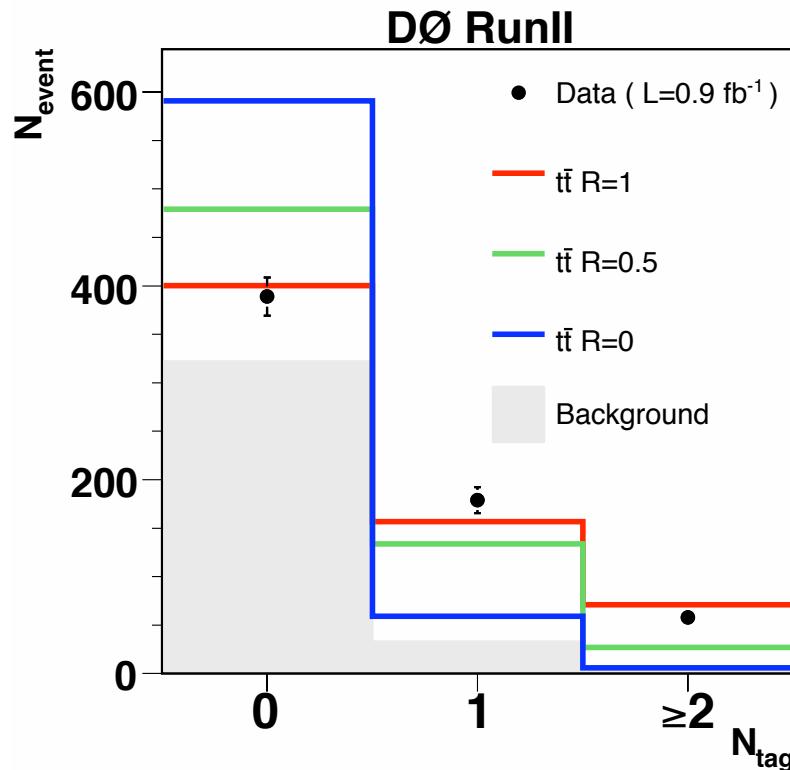
- Utilize several channels
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2-D:

$$F_0 = 0.49 \pm 0.11(\text{stat}) \pm 0.09 \text{ (syst)}$$
$$F_+ = 0.11 \pm 0.06(\text{stat}) \pm 0.05 \text{ (syst)}$$

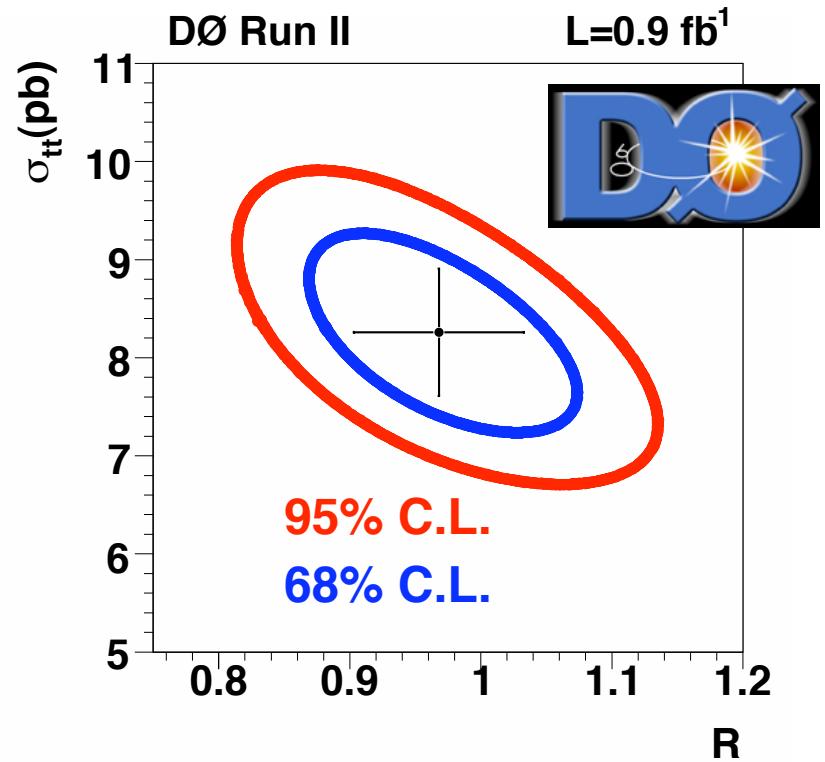


Measurement of R = BR($t \rightarrow W b$) / BR($t \rightarrow W q$)

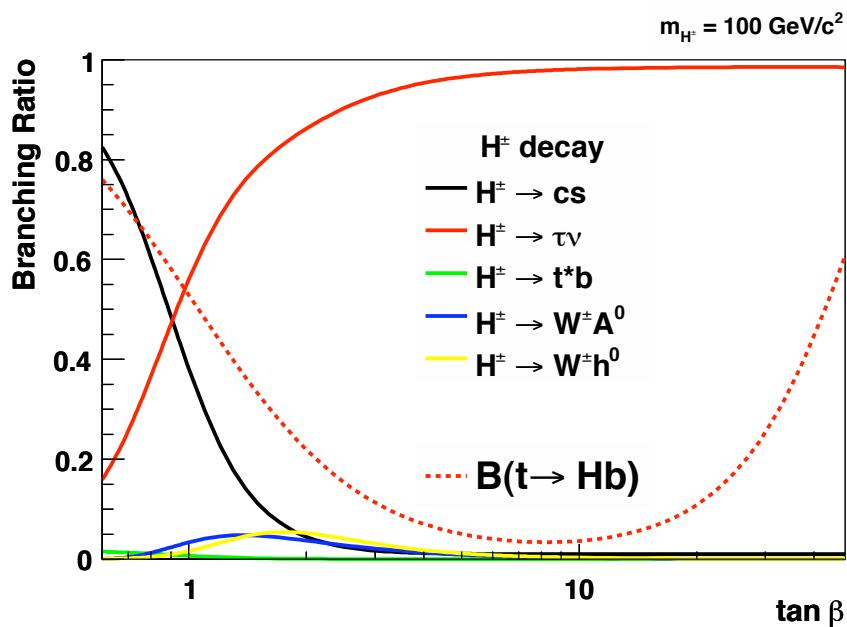


$R = 0.97 \pm 0.09$; $R > 0.79$ @ 95% C.L.
 $|V_{tb}| > 0.89$ @ 95% C.L.

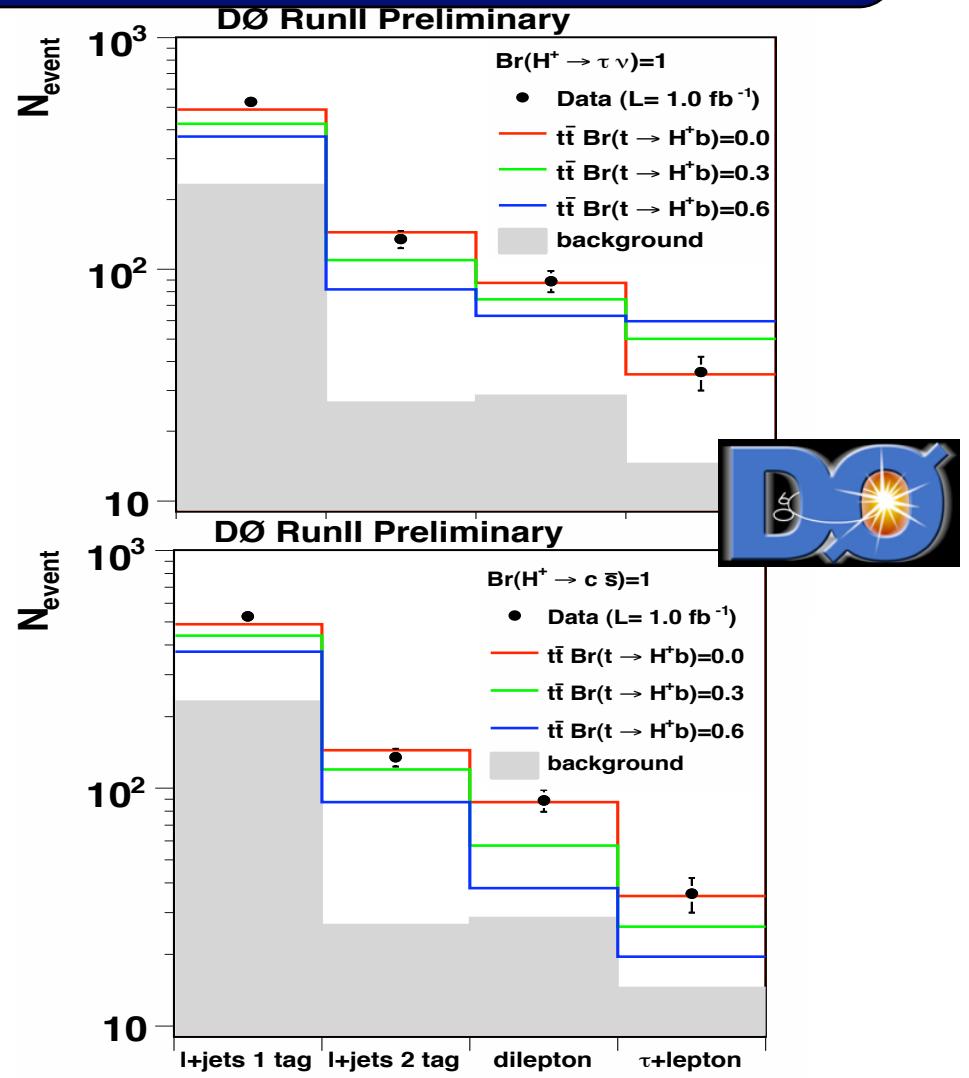
- Using lepton + jets events with and without b-tagging requirement



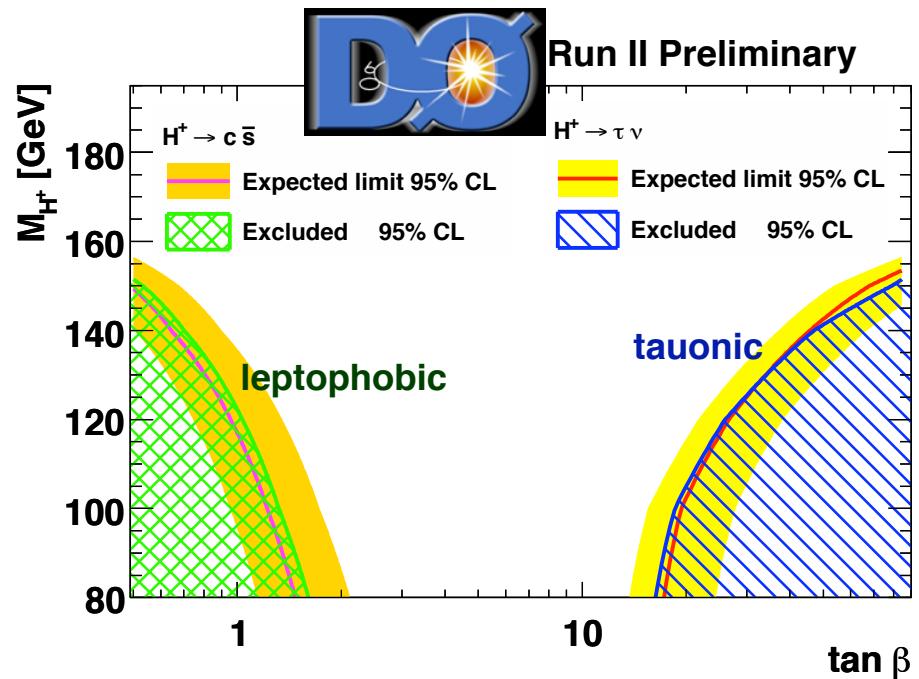
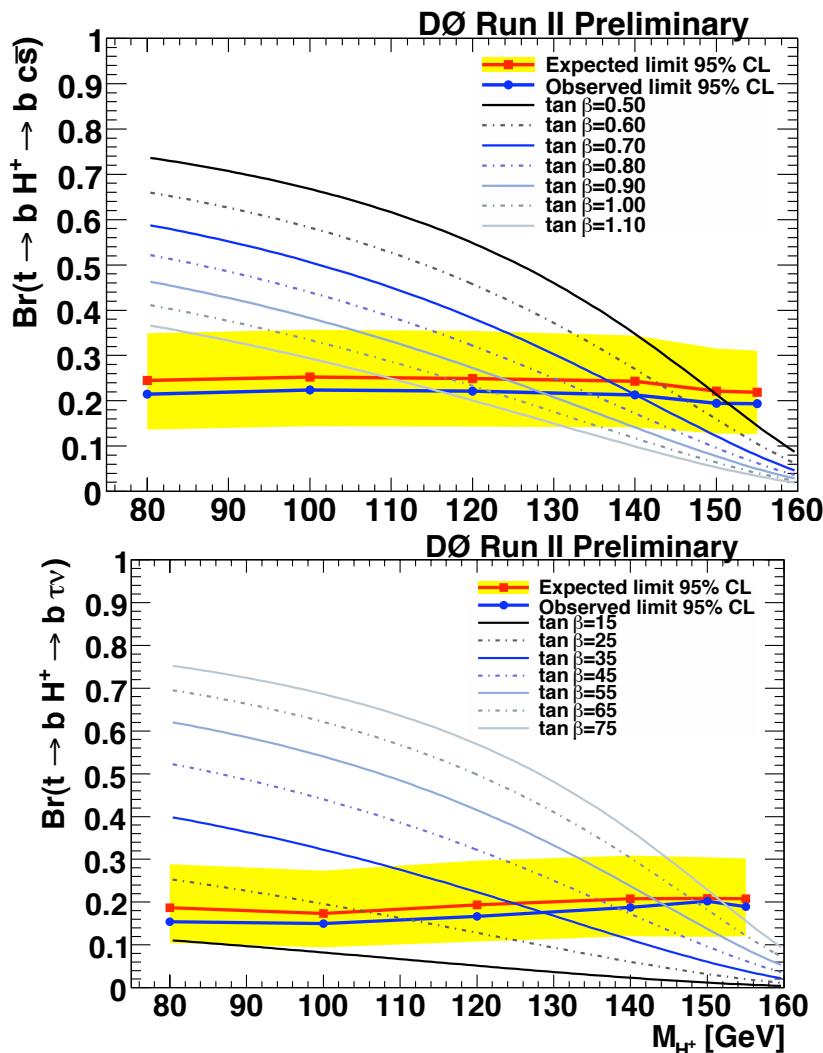
Search for Charged Higgs



- Analyze event yields in several channels simultaneously
- Data prefers no H^+ contribution



Charged Higgs Search Results



Set limits on $\text{BR}(H^+ \rightarrow cs)$ and $\text{BR}(H^+ \rightarrow \tau\nu)$

Limits on charged Higgs mass for

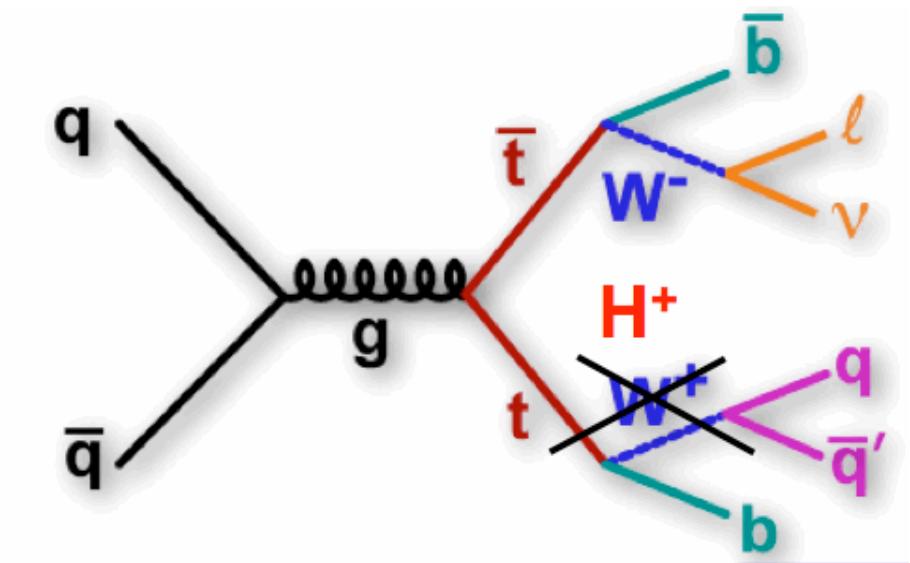
- Leptophobic: ($\text{BR}(H^+ \rightarrow cs) = 100\%$)
 - and tauonic: ($\text{BR}(H^+ \rightarrow \tau\nu) = 100\%$)
- models

Search for Charged Higgs

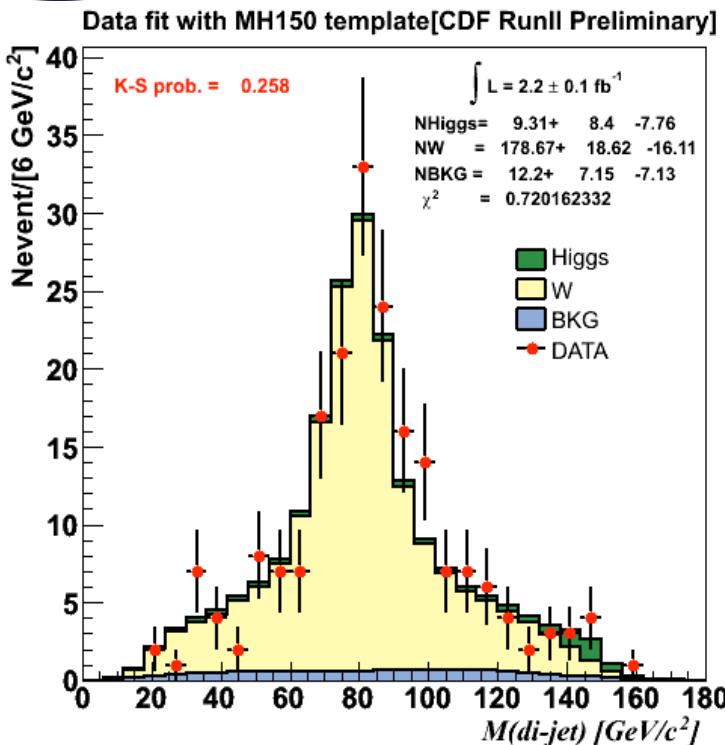


- Explore the possibility that $t \rightarrow H^+ b$ with subsequent $H^+ \rightarrow \bar{c} s$

Reconstruct event kinematics:

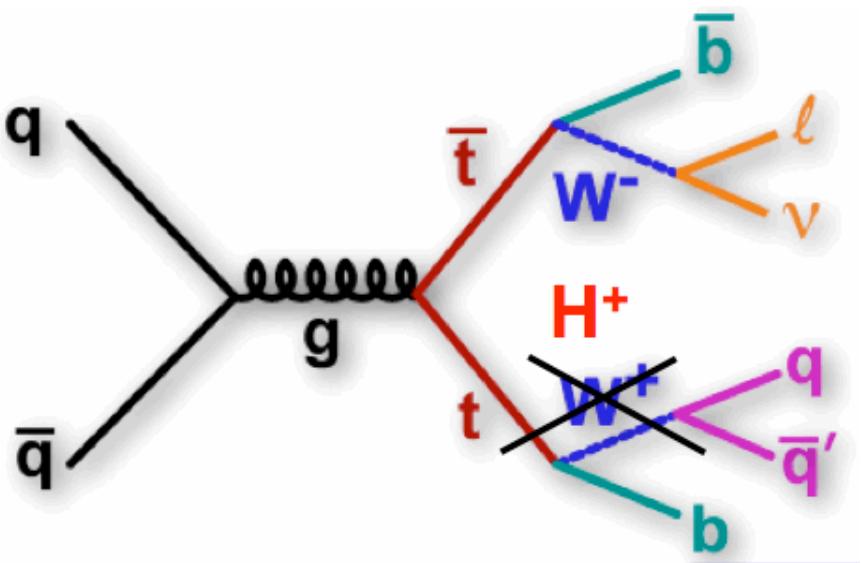


Search for Charged Higgs

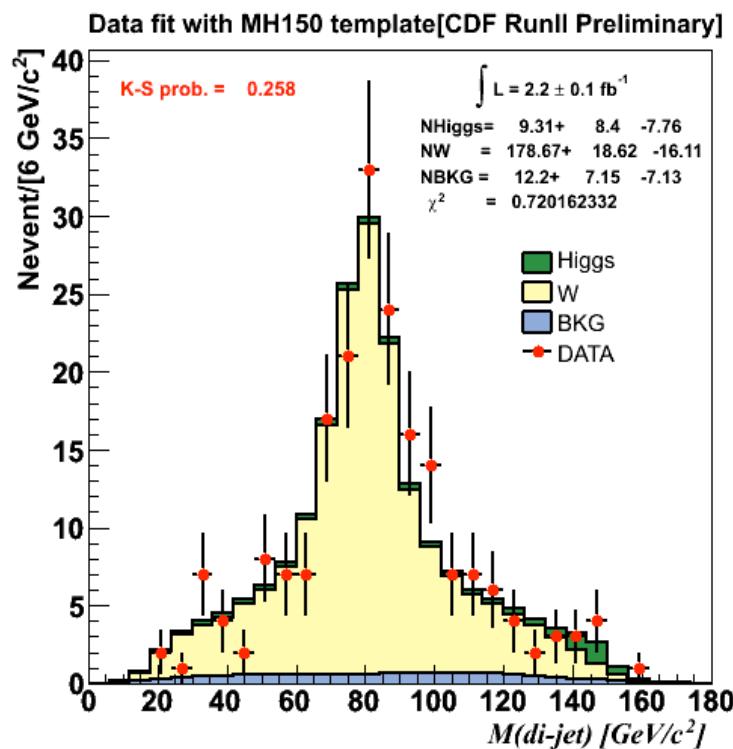


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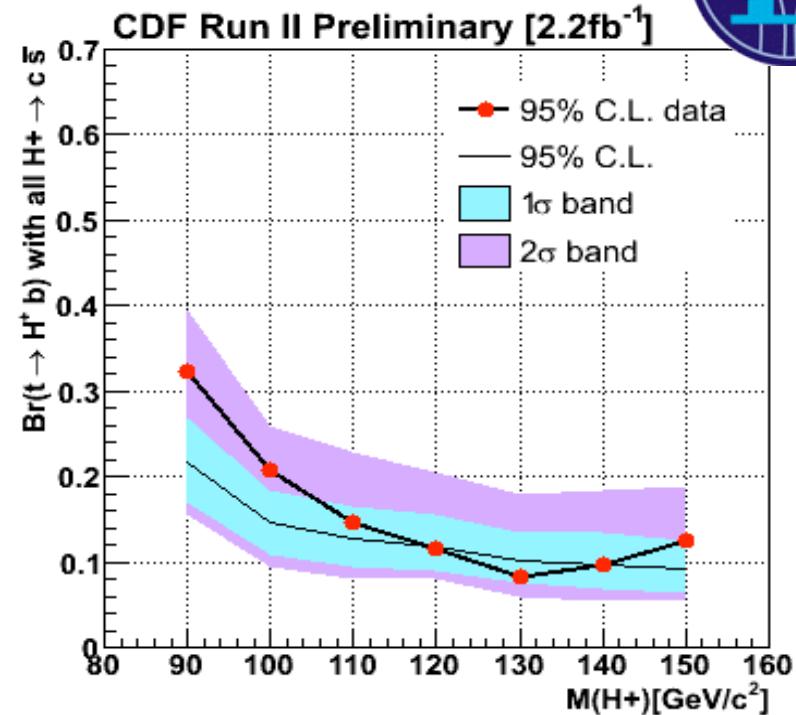
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Charged Higgs Search Results

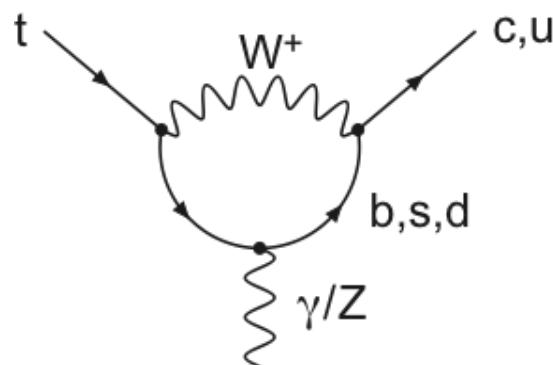


Limit on BR ($t \rightarrow H^+ b$):

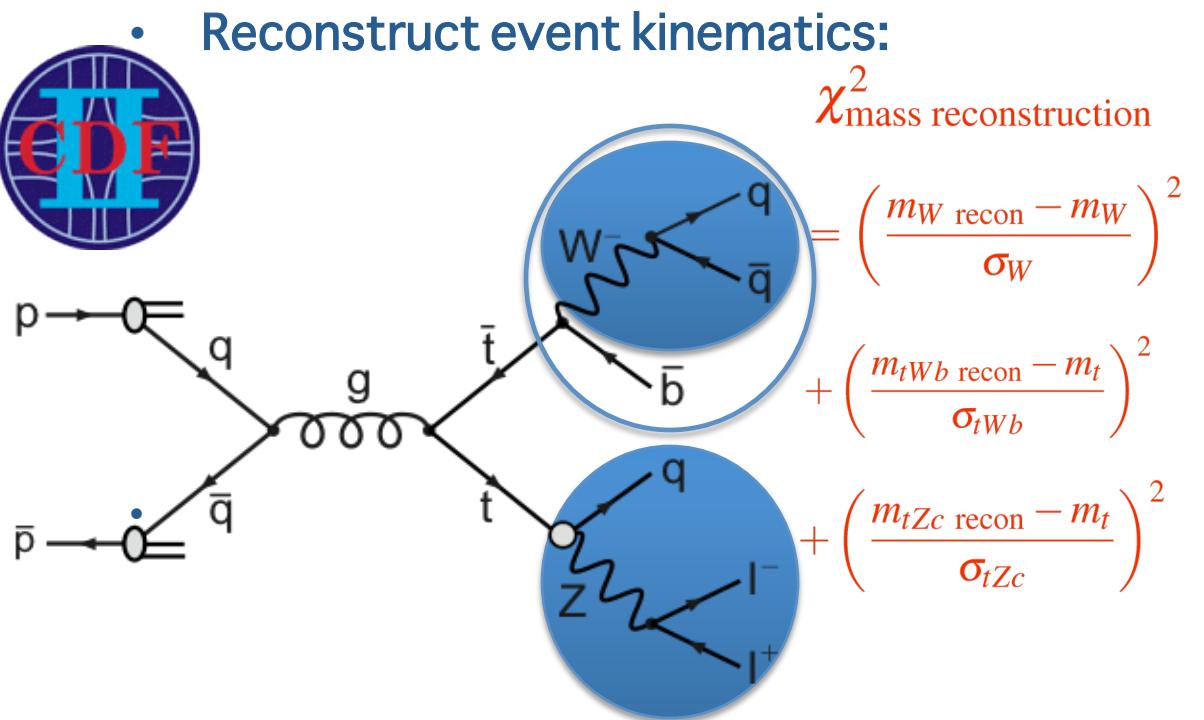


Search for Top Flavor Changing Neutral Currents ($t \rightarrow Zq$)

$\text{BR}(t \rightarrow Zq) \sim \mathcal{O}(10^{-14})$ – extremely rare
Beyond SM can be as high as $\mathcal{O}(10^{-4})$

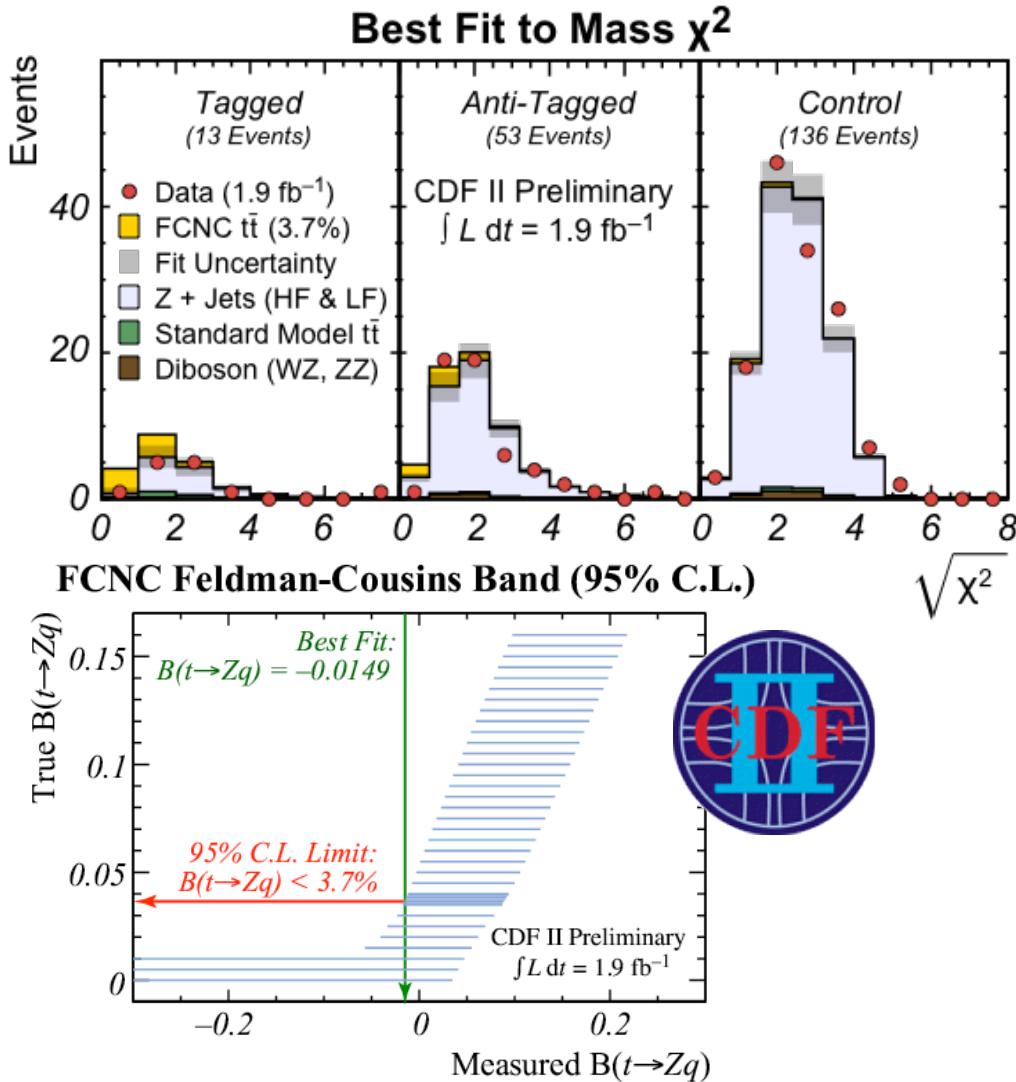


Top FCNC Decay
via Penguin Diagram



- Dominant Background: $Z + 4$ jets

Top FCNC Search Results



- Exploit full kinematics shape instead of counting experiment
- Control systematic shape uncertainties via morphing templates
- Simultaneous fit to mass χ^2 -distribution in two signal and one control regions
- Employ Feldman-Cousins prescription for setting limit

**BR($t \rightarrow Zq$) $< 3.7\%$
(95% C.L.)**

Search for Invisible Top decays

$$\text{Yield} \propto \mathcal{P}(t\bar{t} \rightarrow Wb Wb) +$$

$$\mathcal{P}(t\bar{t} \rightarrow Wb XY) \cdot \mathcal{R}_{Wx/WW}$$

$$\mathcal{P}(t\bar{t} \rightarrow XY XY) \cdot \mathcal{R}_{XX/WW}$$

- Assume theoretical cross section for $t\bar{t}$
- Search for deficit in the event yield

Relative Acceptance when one top decays into Wb while the other one to XY

Relative acceptance when both tops decay to XY



Results:

CDF Run II Preliminary 1.9 fb^{-1}

Decay	$\mathcal{R}_{Wx/WW} (\%)$	Upper Limit (%) (175 GeV)	Upper Limit (%) (172.5 GeV)	Upper Limit (%) (170 GeV)
$\mathcal{B}(t \rightarrow Zc)$	32	13	15	18
$\mathcal{B}(t \rightarrow gc)$	27	12	14	17
$\mathcal{B}(t \rightarrow \gamma c)$	18	11	12	15
$\mathcal{B}(t \rightarrow \text{invisible})$	0	9	10	12

Conclusions

- Top Quark Physics is becoming a precision field
 - Top Properties measurements are still statistically limited
 - So far measurements are mostly consistent with the Standard Model
-
- More Top Physics results are at:
 - http://www-cdf.fnal.gov/physics/new/top/public_tprop.html
 - [http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/
top_public.html](http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_public.html)